Beyond Week 2: Preliminary work toward generating a North American forecast system for Weeks 3-4

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MAPP Webinar: Weather-Climate Linkages

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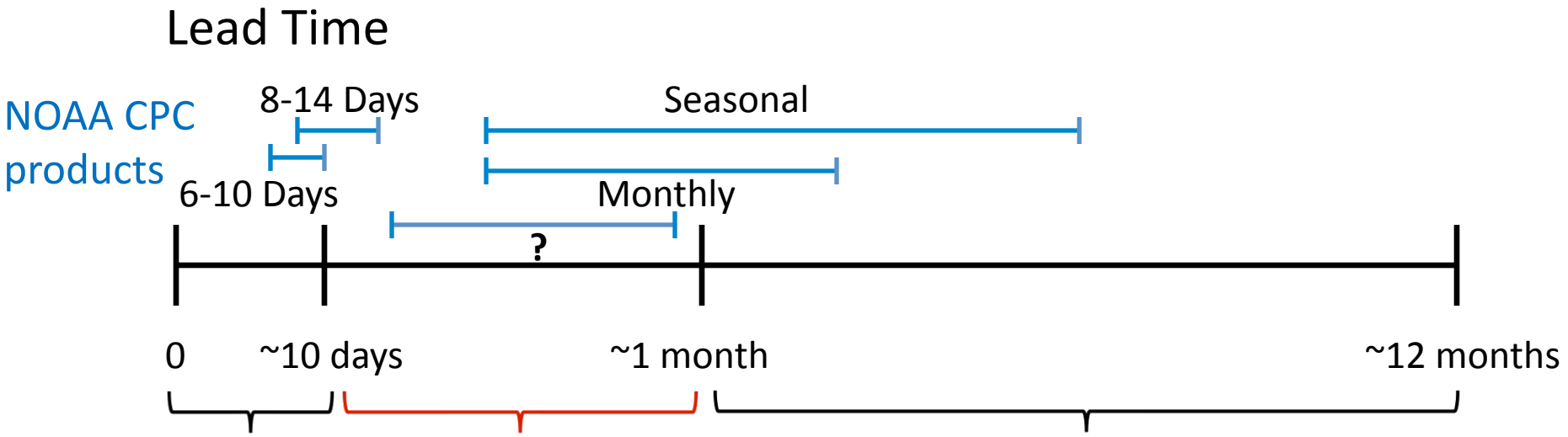
Can we bridge the forecast gap in weeks 3 and 4?



- Based on **initial conditions**
- Rely on numerical weather prediction (NWP) model integrations

Forecast gap:

- Large growth of initial errors
- Timescale too short for boundary conditions to take effect

- Based on slowly varying **boundary conditions**
- Rely on coupled dynamical model integrations and statistical forecast methods

❖ **But there are some sources of predictability for Weeks 3-4**

A heightened focus on forecasts for Weeks 3-4

OBAMA CALLS ON NOAA TO EXTEND OUTLOOKS 15–30 DAYS

October 7, 2014 | At the United Nations Climate Summit in New York City on September 23, President Obama delivered a major speech with a focus on the impacts of climate change in the United States, progress the nation is making in mitigation, and the importance of building resilience and improving our weather and climate prediction capabilities.

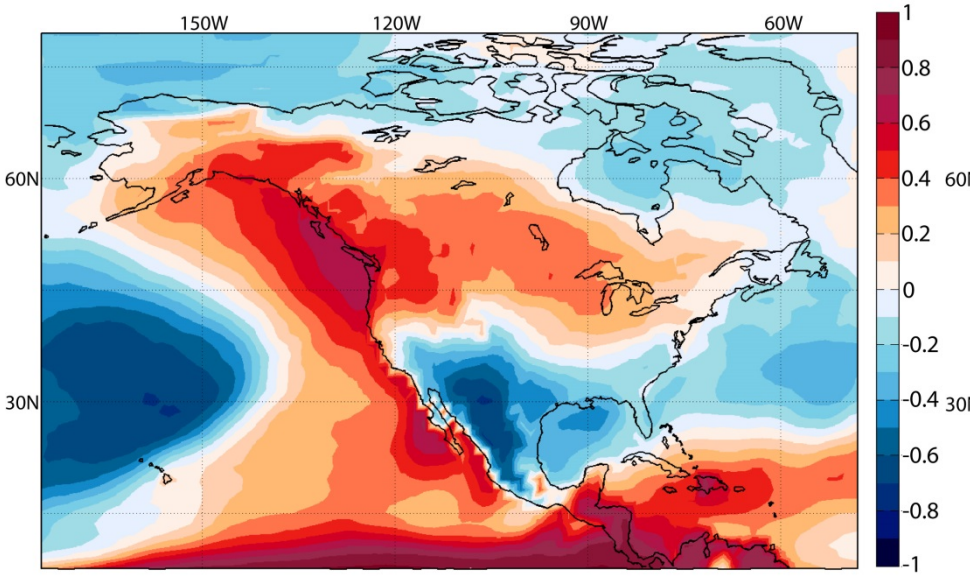
According to a White House fact sheet on these commitments, the Administration intends to begin a coordinated U.S. effort, led by NOAA, to develop reliable extreme weather risk outlooks on time horizons beyond the current 14-day limit for large-scale weather features. This effort will initiate the development of such outlooks in the 15-to-30-day range and will explore potential new information products for the longer time scales on which climate change influences risk.

https://president.ucar.edu/government-relations/washington-update/376/obama-calls-noaa-extend-outlooks

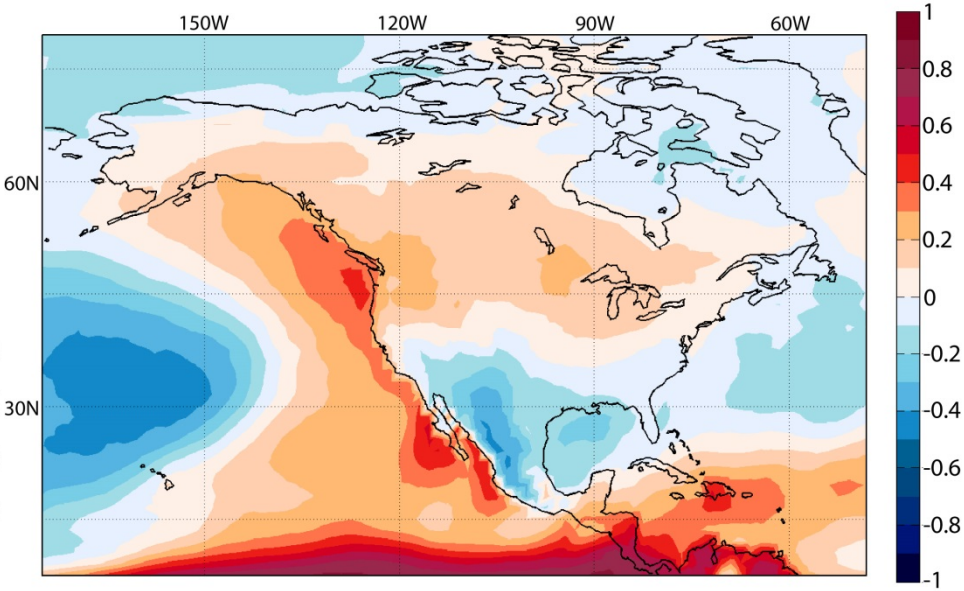
Sources of predictability for Weeks 3-4: The El Niño/Southern Oscillation (ENSO)

Correlation between Niño 3.4 SSTs and T2m (1980-2014)

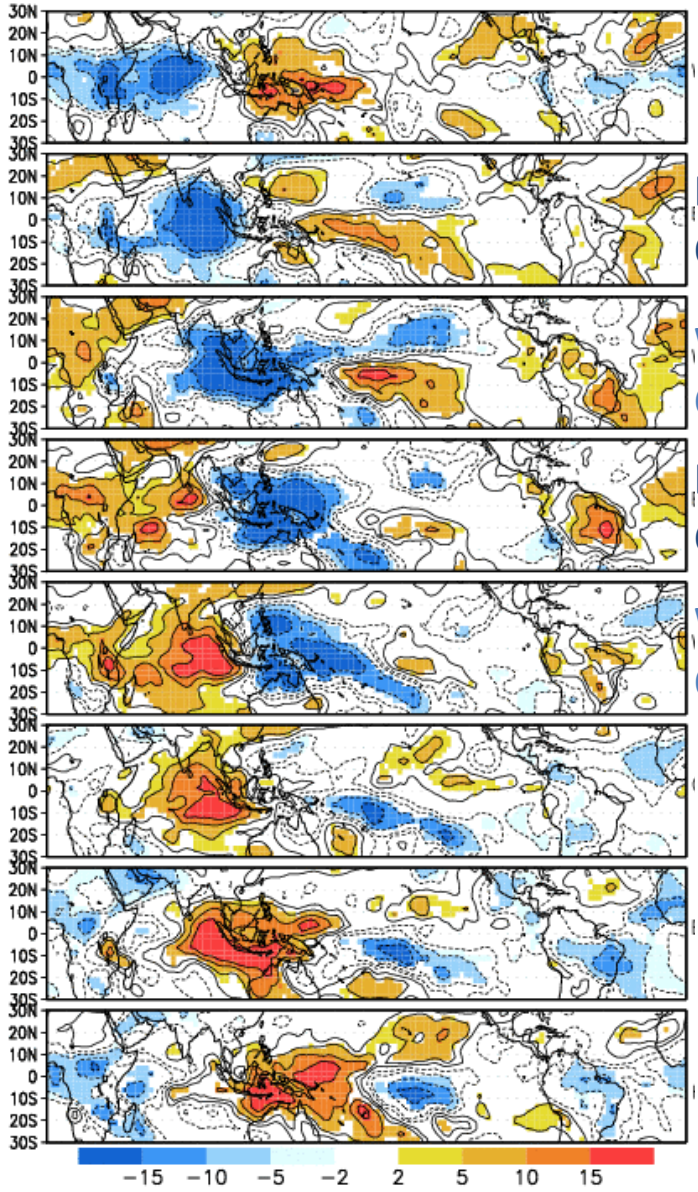
Seasonal mean:
DJFM T2m and Niño 3.4



Weeks 3-4:
14-day mean T2m and lag -14d Niño 3.4



Sources of predictability for Weeks 3-4:
The Madden-Julian Oscillation (MJO)



West Indian Ocean

East Indian Ocean

West Maritime Continent

East Maritime Continent

West Pacific Ocean

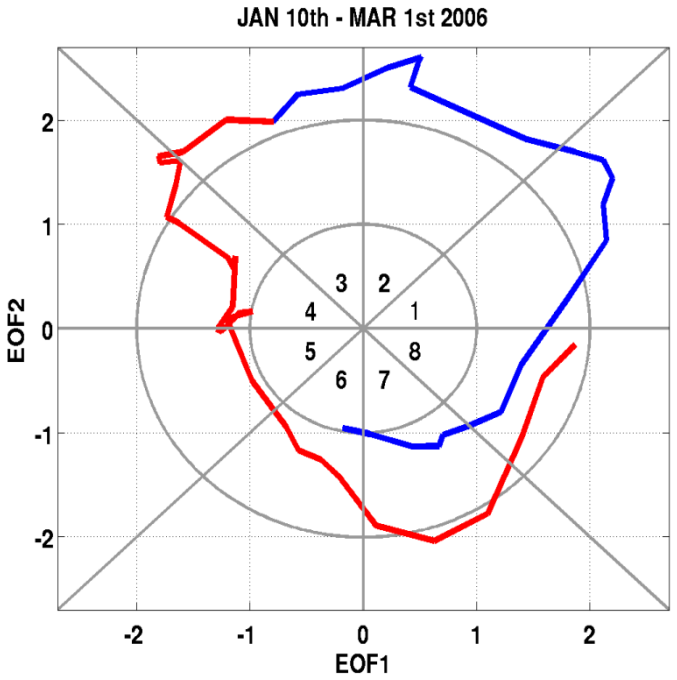
Central Pacific Ocean

East Pacific Ocean

Western Hemisphere

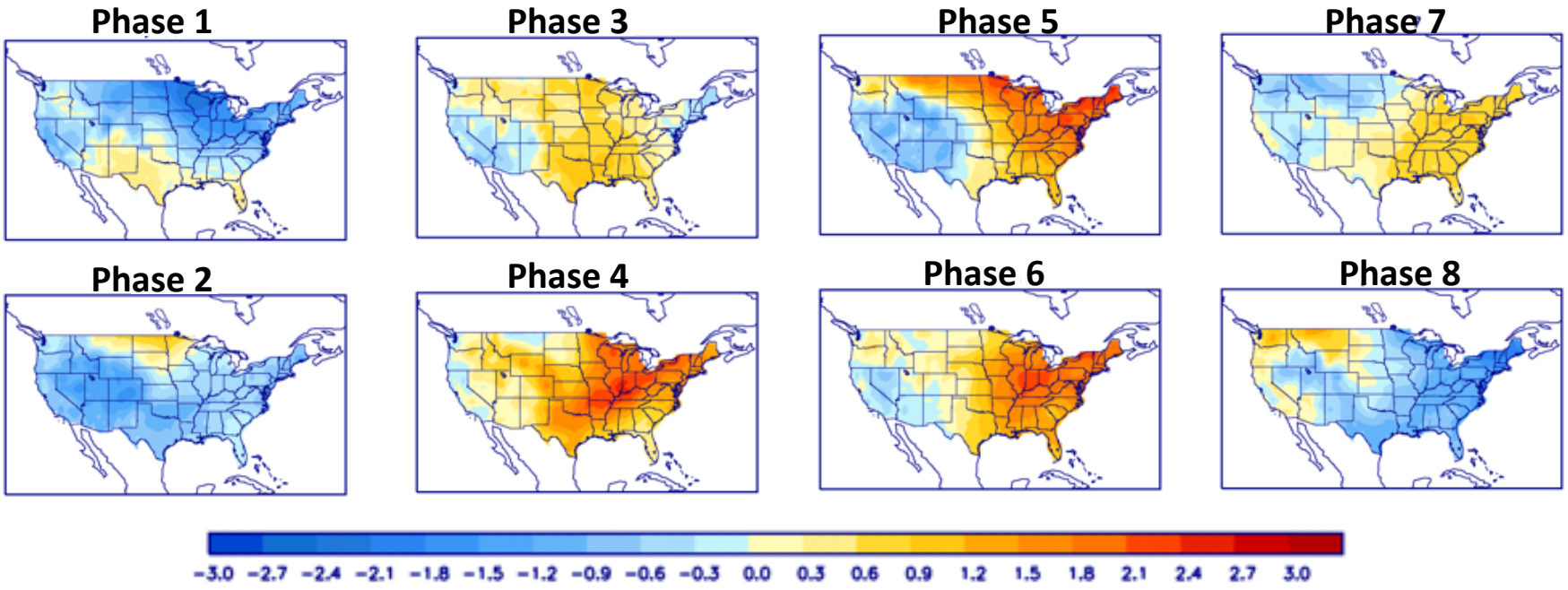
The Wheeler-Hendon Index

OLR anomalies associated with MJO propagation from phase 1 – phase 8 (**blue** = enhanced convection)



Impact of the Madden-Julian Oscillation:
The Wheeler-Hendon Index and US temperatures

Simultaneous surface air temperature composite anomalies (°C, DJF)



NOAA CPC MJO composites page

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/Composites/Temperature/

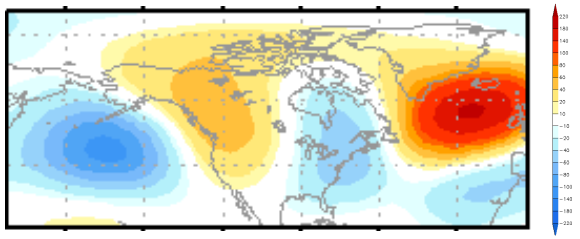
Zhou, L'Heureux, Weaver, and Kumar (2014)

The MJO strongly influences North American wintertime circulation for lead times of up to four weeks.

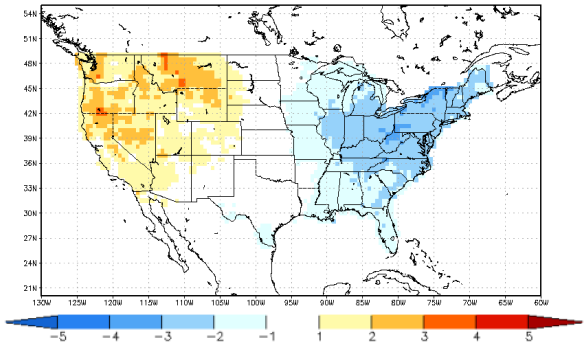
One of the dominant winter atmospheric patterns (top left) strongly affects U.S. temperatures (bottom left).

A weekly cluster pattern

500-hPa height anomalies (m)



Temperature anomalies (°C)

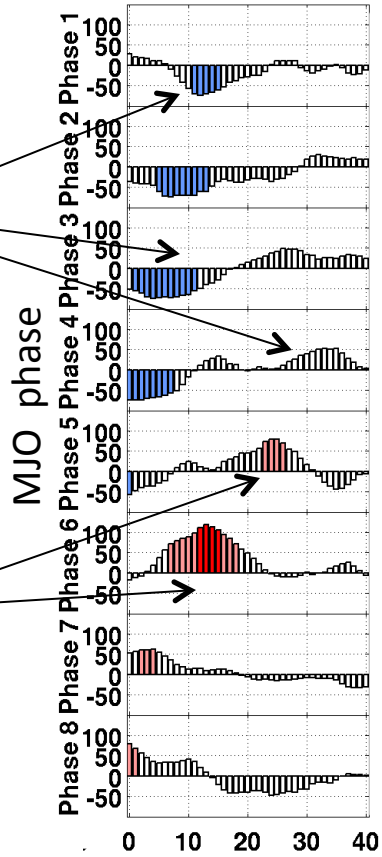


Riddle, Stoner, Johnson, L'Heureux, Collins, and Feldstein (2013, *Climate Dynamics*)

MJO influence on cluster pattern

Anomalous frequency of cluster pattern (top left) occurrence (%)

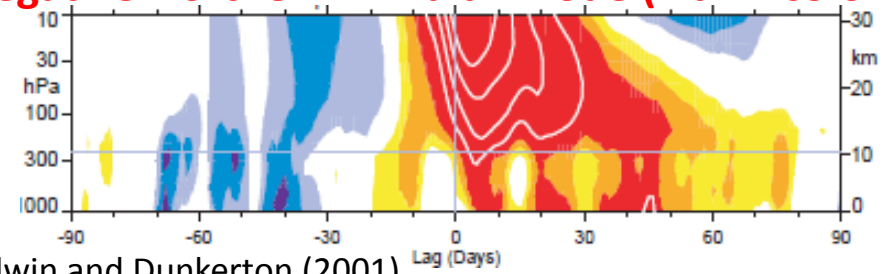
The MJO gives information on pattern occurrence 10-25 days in advance



Other potential sources of predictability for Weeks 3-4:

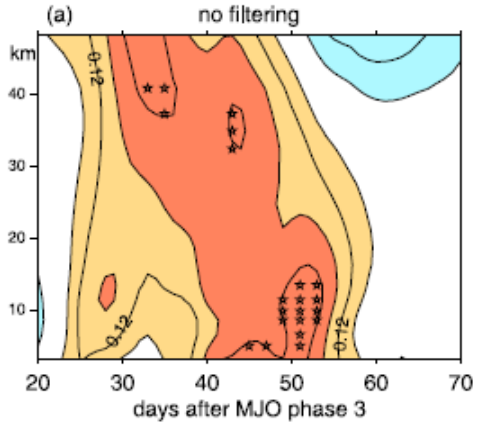
- **Stratosphere-troposphere coupling**

Negative Northern Annular Mode (warm colors)



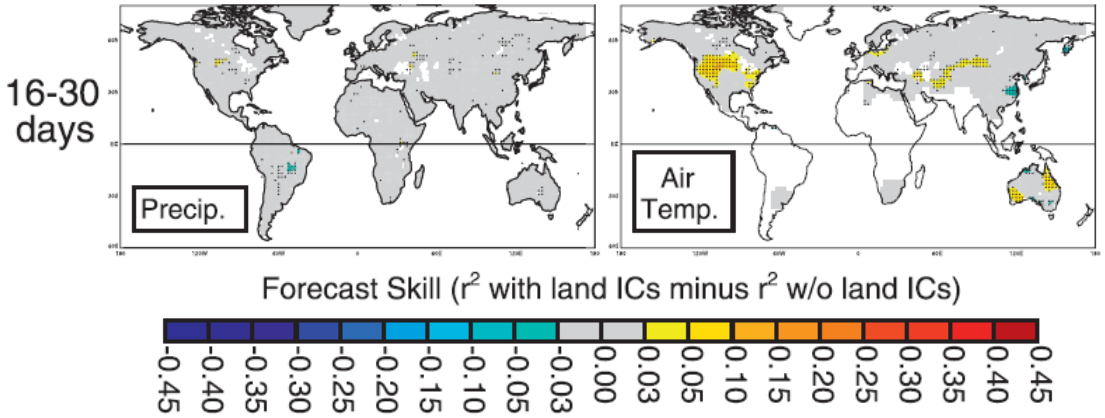
Baldwin and Dunkerton (2001)

Normalized polar cap height



Garfinkel, Feldstein, Waugh, Yoo, and Lee (2012)

- **The land surface (e.g., snow cover and soil moisture) and its role in land-atmosphere interactions**



JJA

Koster et al. (2011)

- **The long-term trend**

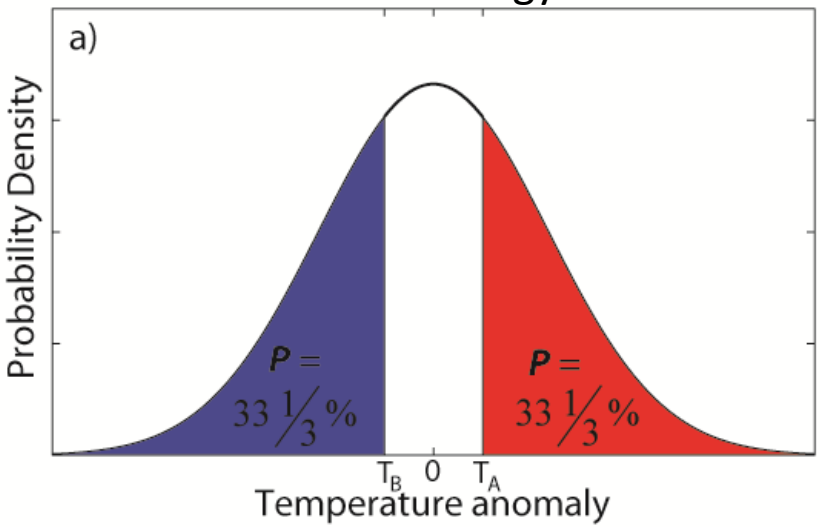
Statistical temperature forecast guidance based on the initial state of the MJO and ENSO

- ERA-Interim 2-m temperature (T2m) data, December – March 1980-2010, North America domain, 7-day running mean anomalies

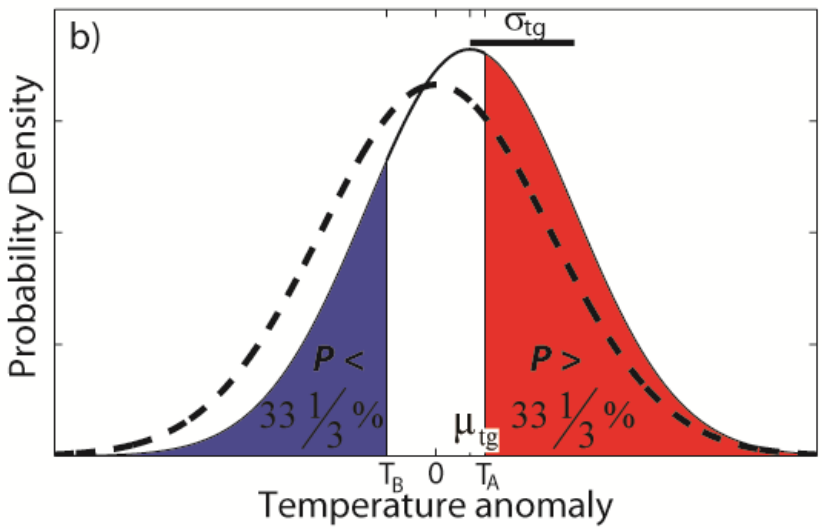
- Main forecast steps:
  1) Calculate mean and variance of T2m anomaly corresponding to MJO and ENSO state; add the two means and variances for each grid point and forecast lag

  2) With the assumption of a Gaussian T2m anomaly distribution and with a linear trend term added, calculate the probability of T2m in the upper and lower tercile for each lead time

Climatology

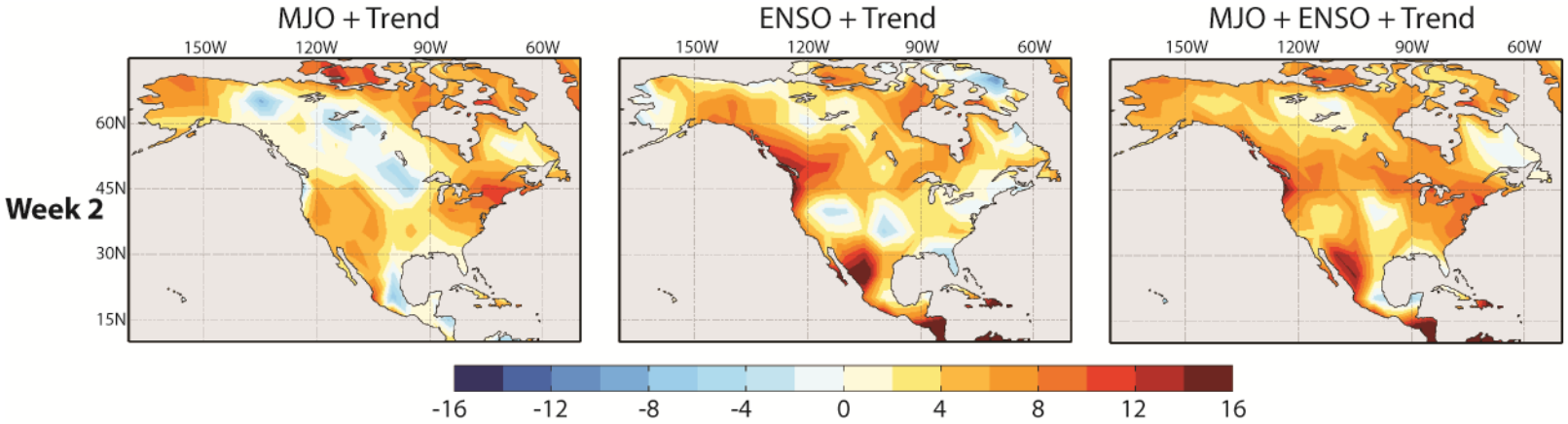


MJO+ENSO+trend forecast

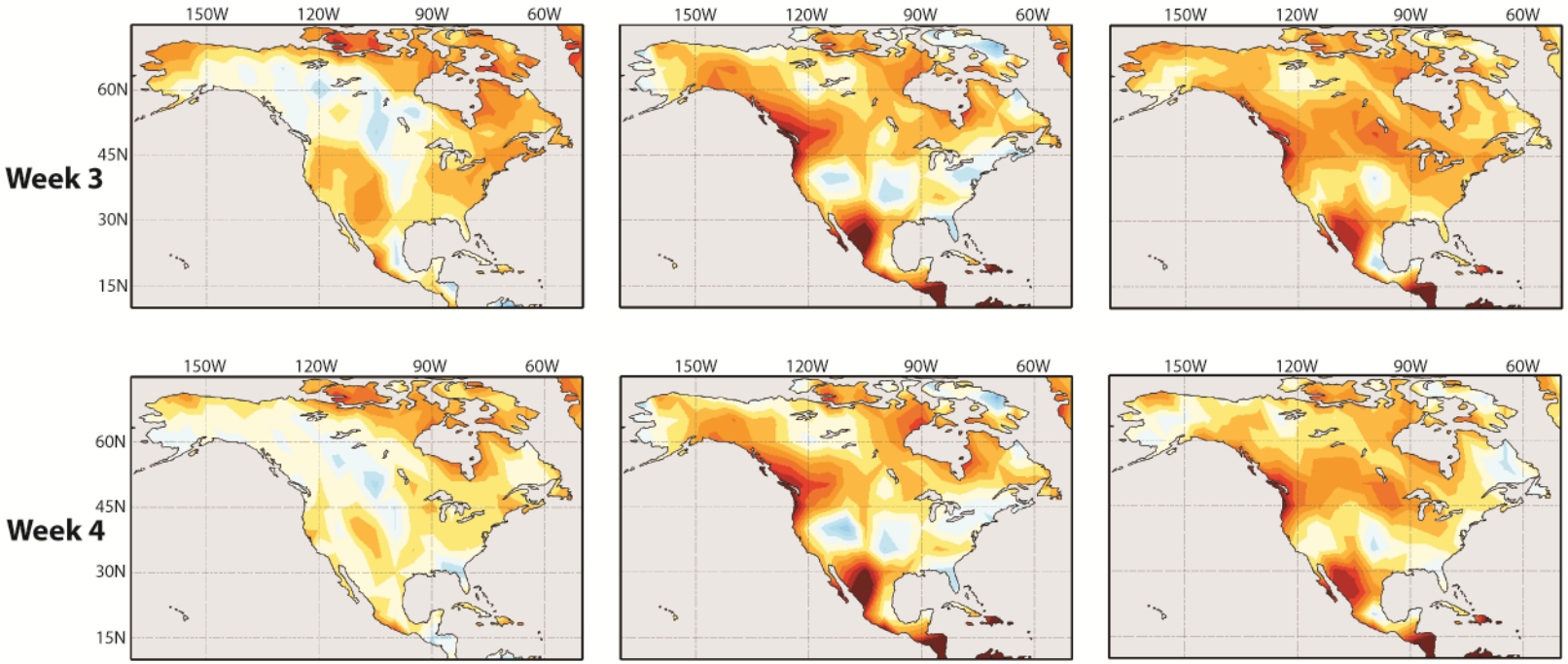


The MJO and ENSO primarily impact different regions of North America.

Mean Heidke Skill Scores (HSS)



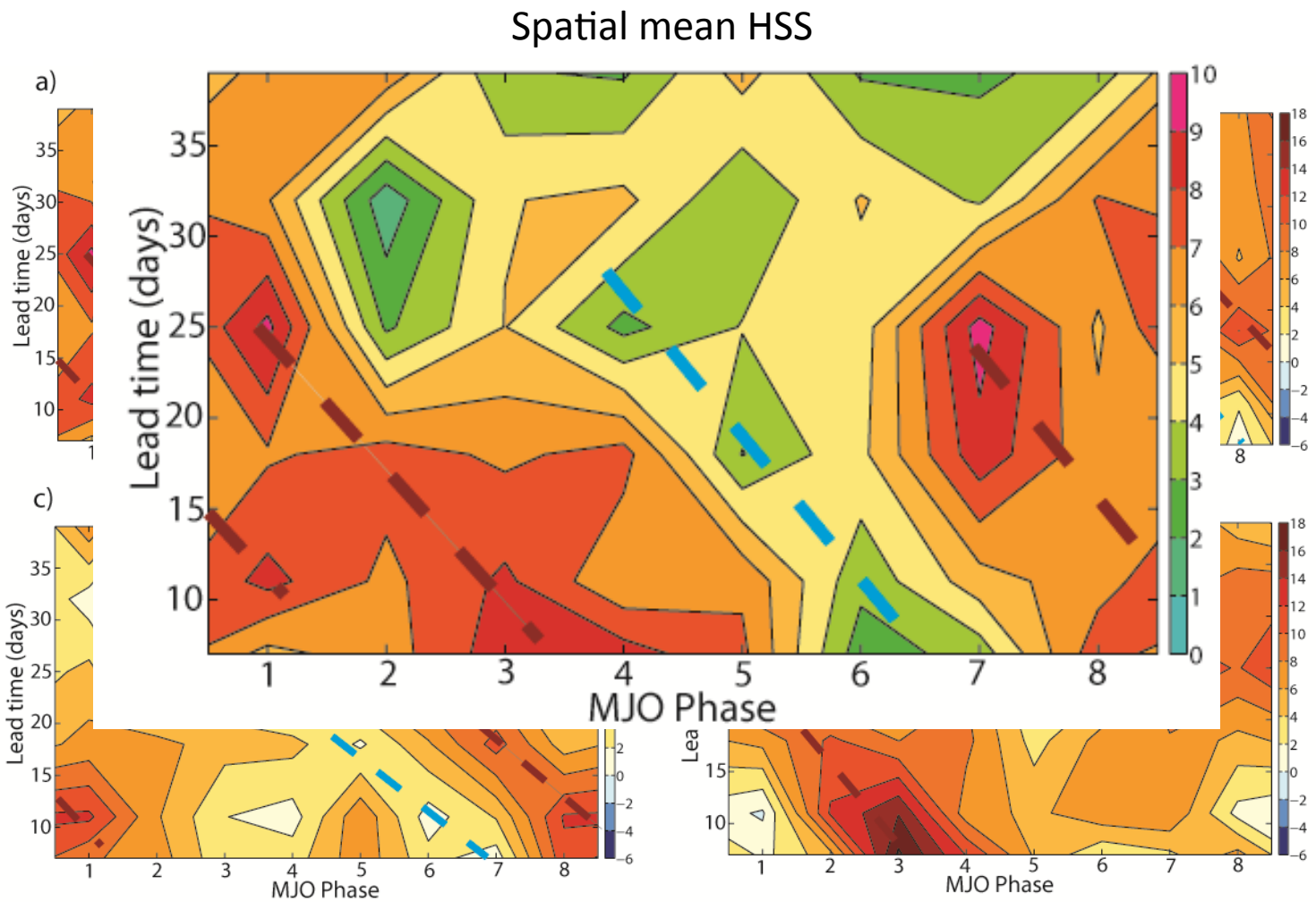
The MJO influence decays between weeks 2 and 4, whereas the ENSO influence remains nearly constant at these timescales.



Johnson, Collins, Feldstein, L'Heureux, and Riddle (2014)

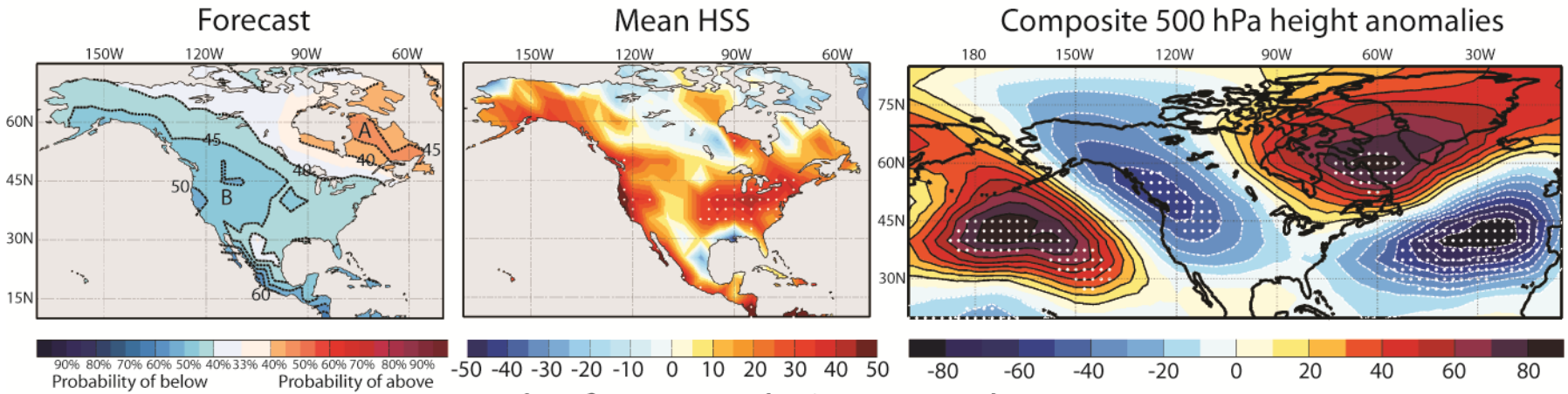
Particular MJO phases have stronger impacts on North American temperatures.

- Lin et al. (2010): response of oppositely signed tropical convective heating anomalies near 80°E and 160°E reinforce each other
- Such an east-west dipole of convective heating corresponds with MJO phases 3 and 7

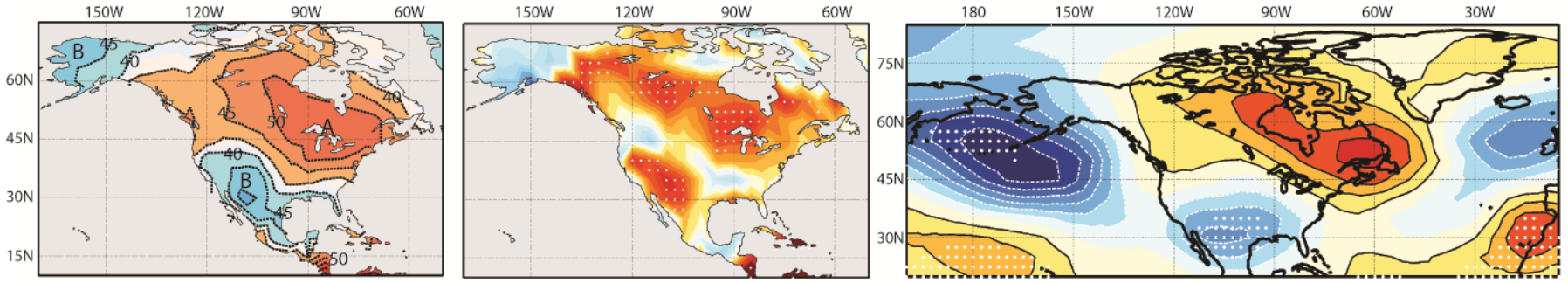


For some initial states of the MJO and ENSO, the skill scores of the weeks 3-4 T2m forecasts from the empirical model are substantially higher than the typical skill scores of dynamical models.

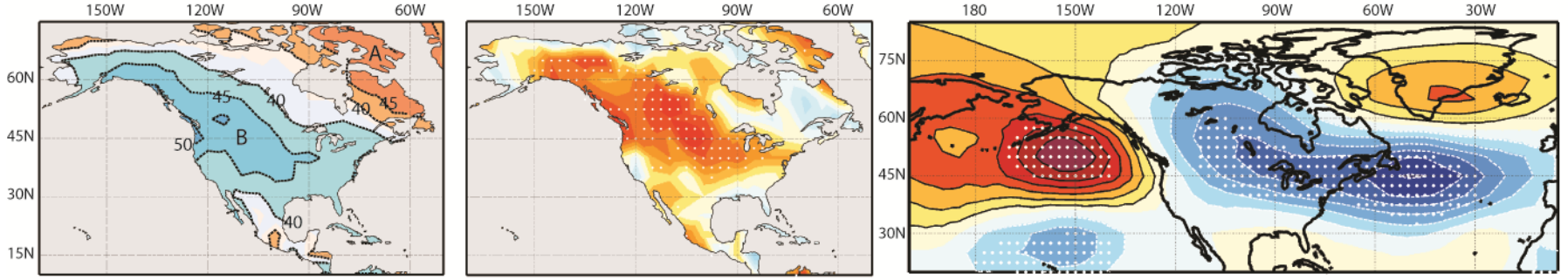
Week 3 forecast, La Nina MJO Phase 8



Week 3 forecast, El Nino, MJO Phase 2

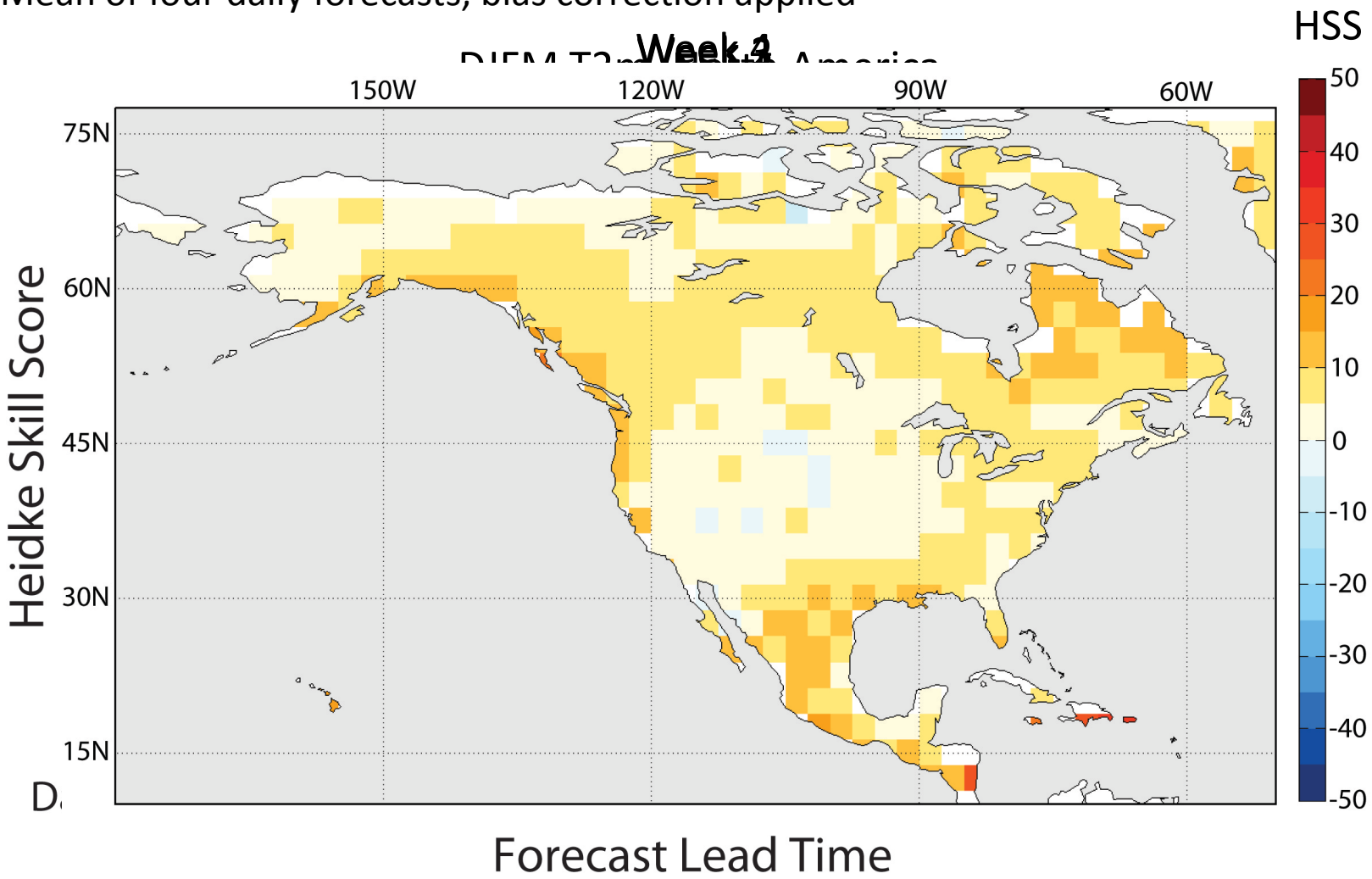


Week 4 forecast, Neutral ENSO, MJO Phase 6

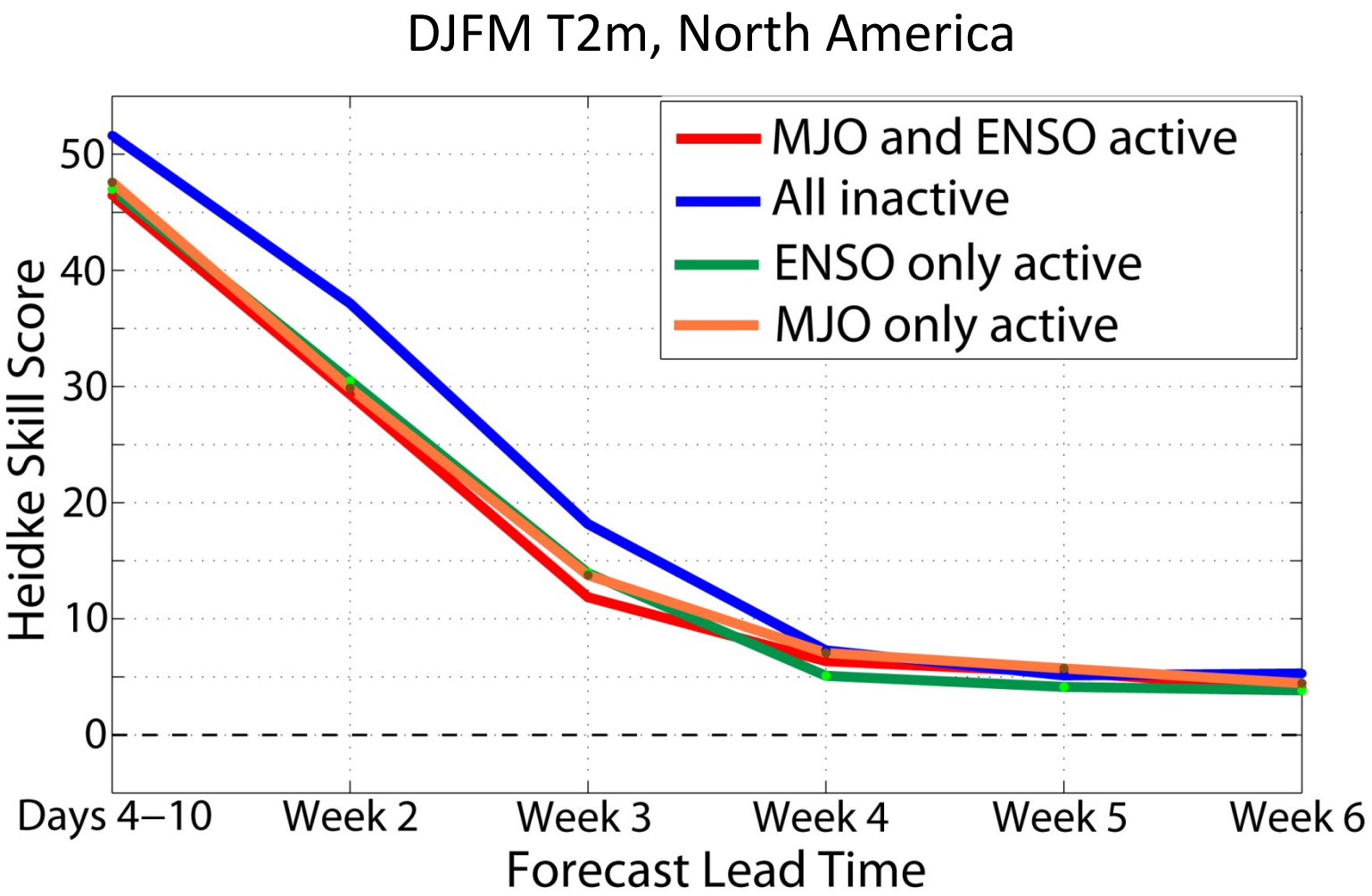


Dynamical forecast guidance:
How well does NCEP's top dynamical model perform in weeks 3-4?

- Climate Forecast System version 2 (CFSv2)
- 4 x daily retrospective forecasts out to 45 days, 1999-2009
- Mean of four daily forecasts, bias correction applied



Do ENSO and the MJO provide "forecasts of opportunity" in the CFSv2?



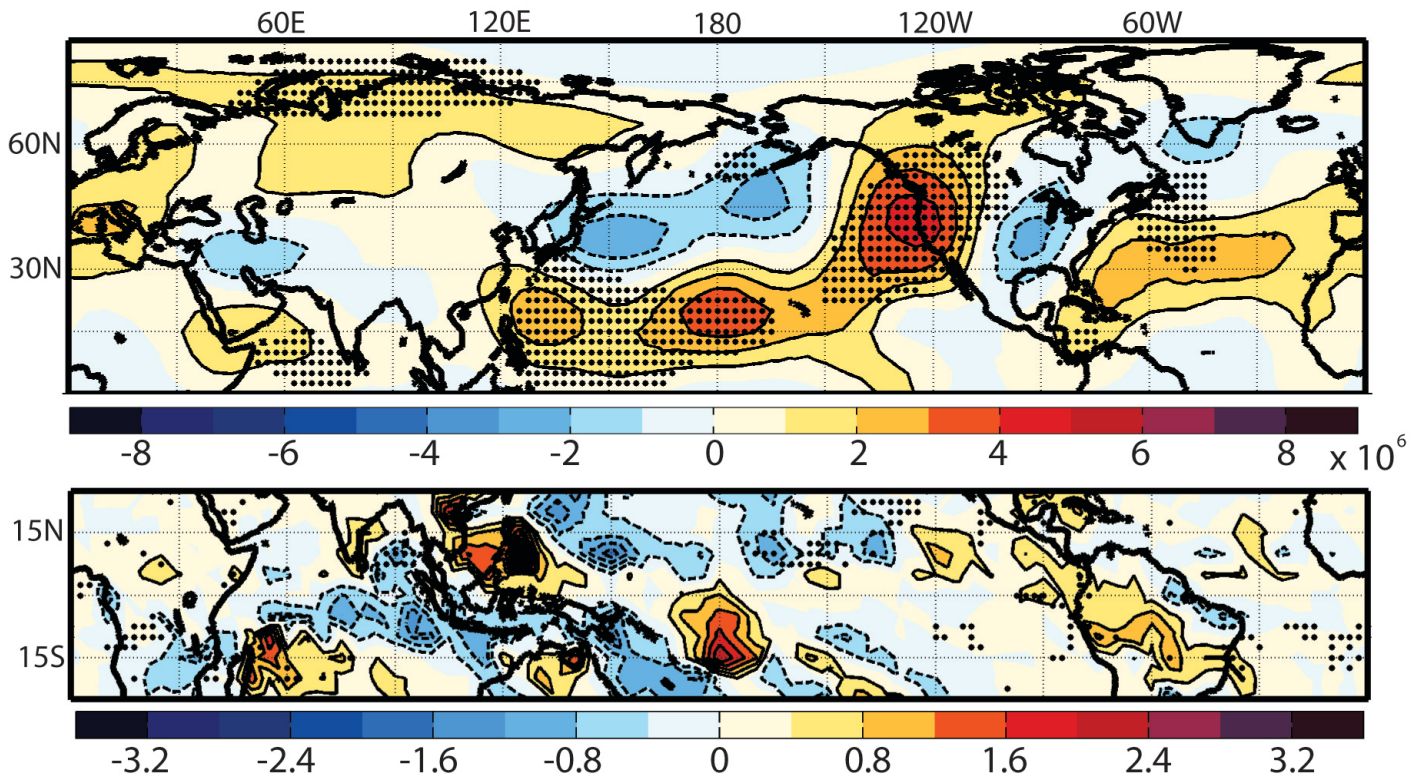
Active MJO: RMM amplitude > 1.0

Active ENSO: El Niño or La Niña by CPC definition

The CFSv2 appears to perform better when the MJO and ENSO are inactive.

Are particular initial conditions associated with high skill in CFSv2?

High (Week3 HSS > 1.0 σ) minus low (Week3 HSS < -1.0 σ) skill composite initial 300-hPa streamfunction and tropical precipitation anomalies



Ψ300 (m^2s^{-1})

Precip ($mm\ d^{-1}$)

Goss and Feldstein (2015, *Mon. Wea. Rev*, in press): Initial atmospheric flow over northeastern Asia, Arctic coast of Siberia, and northwestern North America may have large impact on the extratropical response to the MJO.

Next steps

- Examine **temperature** and **precipitation** predictability for weeks 3-4 in **all seasons**

- Calibrate CFSv2 raw forecasts for probabilistic Weeks 3-4 outlooks (can we leverage high vs. low skill states in the calibrations?)

- Extend to multi-model ensembles? (Sub-seasonal NMME?)

- Investigate the physical mechanisms associated with predictability in Weeks 3-4

Conclusions

- A simple empirical model for probabilistic T2m produces skillful Weeks 3-4 forecasts in winter for certain initial states of the MJO/ ENSO.
- Bias-corrected CFSv2 T2m forecasts also exhibit skill over the Pacific Northwest coast, the Gulf States, and the eastern U.S. Lower skill is evident over the Intermountain West and central U.S.
- High skill in Weeks 3-4 in the CFSv2 is not tied to active MJO or ENSO.
- Skill exhibits some sensitivity to the initial atmospheric flow.
- Ongoing efforts to extend the statistical forecast guidance and to calibrate NCEP's dynamical models for probabilistic forecasts